AREAL AND STRATIGRAPHIC DISTRIBUTION OF THE STEEP SIDED DOMES: PRELIMINARY RESULTS OF THE REGIONAL MAPPING OF VENUS.

M.A.Ivanov[1] and J.W.Head[2]; 1- Vernadsky Institute, Russian Academy of Sci., 117975; 2- Dept. of Geol. Sci, Brown Univ., Providence, RI 02912

Introduction: Steep-sided domes, discovered in the very beginning of the Magellan mission [1-5], are thought to be of volcanic origin but the details of their mode of emplacment and composition is still under debate. The unusual shape of the domes is in sharp contrast to the morphology of common basaltic lava flows and edifices. The morphology of the domes suggests that either the domes formed as the result of combination of low eruption rate and ambient conditions on the Venus surface [6] or their material was more viscous (due to more silicic composition of the magma [4,7], its higher degree of crystallization [8] or abundant bubbles [4, 9]) compared with common basaltic lava. We have mapped a complete band around the globe along 30N (from 22.5 N to 37.5N) based on the C1-MIDRPs mosaics. The mapping showed both the areal distribution of the domes and their stratigraphic position which helps to put constraints on the process of dome formation.

Areal distribution, associations, and stratigraphy of the domes: There are 41 steep-sided domes within the mapped area which represents about 12% of the planet's surface. If one to extrapolate the observed number of the domes, than the expected number of the domes on Venus will be about 300-400. This number more than twice larger than the published data [4] mostly because many of the domes were overlooked in the erlier studies. The domes are unevenly distributed in the mapped area and concentrated in three narrow latitudinal segments, 14-30, 190-240, and 300-340E, where the number of the domes is 7, 10, and 20, respectively. Such a distribution of the domes is probably the result of the well-known tendency of the domes to make clusters [4]. Of 41 domes, 24 features make groups of 2-4 domes where the distance between the neighboring domes is close to or less than their average diameter; some dome pairs consist of two overlapping domes. Seventeen domes are self-standing (single dome in a whole C1). Several of these domes (6) are flooded by the surrounding plains and there is the possibility that the domes are remnants of the buried clusters.

Two domes associate with large volcanoes and embayed and partly covered by young lava flows from the volcanoes. It is unclear if the domes predate the volcano formation or formed along with the volcanoes. Four domes associate with the belts of fractures and superposed onto the fractures. Fifteen domes associate with coronae and corona-like features. The corona domes are, as a rule, untouched by the fractures typical of the corona rim and look to be superimposed onto rim of coronae. This suggests that the dome emplacement took place after formation of the majority of the typical corona deformation. Half of the mapped domes (20) does not display visible association with any large volcanic and tectonic centers. Instead, the domes occur inside the fields of small shields.

To assess the stratigraphic position of the domes it is necessary to introduce the stratigraphy we used during the mapping [10-12]. The stratigraphic scheme consists of nine units. Relationships between them are consistent over the mapped area. The units are as follow (from older to younger): *Tessera terrain* (Tt); *Densely fractured plains* (Pdf); *Fractured and ridged plains* (Pfr)*/Ridge Belts* (RB); *Fracture Belts* (FB); *Shield plains* (Psh); *Plains with wrinkle ridges, lower member and upper members* ($Pwr_{1,2}$); *Lobate plains* and *Smooth plains* (Pl/Ps).

Thirty-five domes (85% of all domes mapped) occur within the fields of small shields which make up the Psh unit. There is evidence that the domes formed during the formation of shield plains: i) the domes inside Psh do not display deformational pattern typical of the material predating the shield plains [13]; ii) sometimes the small shields occur on top of some domes; iii) where the domes are at the edge of the Psh occurrences both the domes and Psh embayed by the younger regional plains with wrinkle ridges.

Four more domes embayed by the regional plains with wrinkle ridges, $Pwr_{1,2}$. It makes the domes to be older than the regional plains. On the other hand, the domes display no deformation typical of the units predating shield plains (Tt, Pdf, Pfr/RB, FB). Near the domes within the regional plains there are occurrences of the shield plains. This could mean that the flooded domes also belong to Psh and represent kipukas of the unit. The stratigraphic position is unclear only for two domes which are in the association with the large volcanoes and embayed by the youngest lobate plains (Pl). Thus the most important characteristic of the stratigraphy of the steep-sided domes is that almost all of them (39 of 41) are older than the regional plains with wrinkle ridges, Pwr_1 and the majority of the features belongs to one stratigraphic unit, Psh.

Discussion: The unusual morphology of the steep-sided domes could be due to either unusual conditions of the eruption of dome material (low eruption rate combined with the cooling effect of the atmosphere [6]) or unusual rheological properties of the domes' material (higher viscosity). The first hypothesis has at least three probabe consequences. First, the wide range of eruption rate, under which the domes could form, would lead to the wide distribution of the domes because volcanic activity is widespread on Venus [2] and the cooling effect of the atmosphere should be about the same almost everywhere. Second, if the range of the eruption rates is narrow, it would probably lead to the narrow range of dome dimensions. Third, the domes could form in any period of the Venus' geologic history if one to assume that the atmosphere conditions were stable over that time.

The characteristics of the areal distribution of the domes and their apparent stratigraphic position, revealed by our mapping, seem to disagree with the above conclusions of the first hypothesis for the dome formation. The first conclusion contradicts the observed uneven areal distribution of the domes and their tendency to make clusters. The clusterization of the domes could be due to a narrow permissible range of the eruption rates. However, it probably disagrees with the large variations of the dome diameters (from 11 to 118 km within the mapped area, the average diameter is 28.6 km, and the standard deviation is about 19 km). The observed close relation of the domes with one unit, Psh, disagrees with the third conclusion. That is why it is hard to explain the formation of the steep-sided domes purely by the interaction of the eruption rate and the cooling effect of the atmosphere. Thus the main reason for dome formation may be the higher viscosity of their material. The higher viscosity of the dome magma could be due to either its more silicic composition [7] or higher degree of crystallisation [8] or higher content of the gas bubbles [4, 9] or combination of these.

A more silicic composition of magma could be due to direct remelting of the non-basaltic (more silicic) substrate making up the wall rocks [4]. Uneven areal distribution of the domes, their tendency to make clusters, and close association with one stratigraphic level strongly disagrees with the proposed existence of a hypothetical widespread non-basaltic substrate on Venus [14,15]. Otherwise, one would expect a wide distribution of the domes in time and space. If the domes, nevertheless, formed through the remelting or assimilation of the more silicic material, the accumulations of such a material may occur locally in areas of the present-day concentrations of the domes.

Another possibility to make more silicic magma is its chemical differentiation, which requires the magma stalling in the chamber [4]. This stalling would also lead to a higher degree of crystallisation and higher content of gas bubbles in some portion of the magma body as well. Thus the single process, magma stalling, explains all three possible reasons for the apparently high viscosity of the domes' material. The idea that the main factor in the formation of higher viscosity material is magma stalling is supported by the close relation of the domes with one stratigraphic unit, Psh. The unit is characterized by concentration of small (a few km in diameter) volcanic shields [16]. The large number of shields typical of Psh means that they probably formed through secondary sources when the main magma body stalled at some rheological boundaries [2].

Although magma stalling could be the main factor, the other effects, say the rate of chamber emptying, may play an important role in the formation of the steep-sided domes in each certain case. That means that for the accumulation and eruption of a significant amount of more viscous magma it may be necessary to combine several factors and such a combination may explain the clusterization of the domes within Psh itself.

Conclusions: Our detailed mapping showed that the steep-sided domes are unevenly distributed and usually make clusters within the mapped area. Almost all domes spatially associate with one stratigraphic unit of shield plains (Psh). These characteristics of the areal distribution and geologic position of the domes disfavour the hypothesis that the domes formed mostly due to a certain combination of eruption rates with the cooling effect of the atmosphere. Instead, a more plausible reason for dome formation is the higher viscosity of their material. The single process, magma stalling, could explain all three factors for increased viscosity (more silicic composition of magma due to chemical differentiation, higher degree of crystallisation, and higher content of bubbles). If, nevertheless, the higher viscosity is due to direct remelting of the non-basaltic (more silicic) substrate, such a material can not be widespread on Venus and probably make up only local accumulations.

References: 1) Head,J.W. et al., *Science*, 252, 276, 1991, 2) Head, J.W. et al., *JGR*, 97, 13153, 1992, 3) Guest,J.E. et al., *JGR*, 97, 15949, 1992, 4) Pavri,B. et al., *JGR*, 97, 13445, 1992, 5) Basilevsky,A.T. et al., *JGR*, 97, 16315, 1992, 6) Gregg,T.K.P. and Sakimoto,S.E.H. *LPSC XXVII*, 459, 1996, 7) Fink,J.H. et al., *GRL*, 20, 261, 1993, 8) Pinkerton,H. et al., *LPSC XXV*, 1089, 1994, 9) Head,J.W. and Wilson,L. *JGR*, 97, 3877, 1992, 10) Basilevsky,A.T. and Head,J.W. *EMP*, 66, 285,1995, 11) Basilevsky,A.T. and Head,J.W. *Planet.Space.Sci.*, 43, 1523, 1995, 12) Head,J.W. and Ivanov,M.A. *LPSC XXVII*, 515, 1996, 13) Bridges,N.T. and McGill,G.E. *LPSC XXVII*, 165, 1996, 14) Nikolaeva, O.V. et al. *LPSC XIX*, 864, 1988, 15) Nikolaeva, O.V. et al. In: *Venus Geology, Geochemistry, and Geophysics (Research Results from the USSR)*, V.L.Barsukov et al. eds., Univ. Arizona Press, 129, 1992, 16) Aubele,J.C. *LPSC XXVI*, 59, 1995